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NUMERICAL ANALYSIS AND MODELING
OF ATMOSPHERIC PHENOMENA

Principal Investigator: Professor Peter H. Stone

Center for Meteorology and Physical Oceanography
Department of Earth, Atmospheric and Planetary Sciences
Massachusetts Institute of Technology
Cambridge, MA 02139

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Summary

For the past 22 years Grant NGR 22-009-727 has been supporting research in the Center for Meteorology and Physical Oceanography (and its predecessors) in a wide variety of diagnostic and modeling studies of atmospheric and ocean phenomena. Professor Jule Charney was the initial Principal Investigator. Professor Peter Stone joined him as co-Principal Investigator in 1975 and became the sole Principal Investigator in 1981.

During its lifetime the Grant has supported in whole or in part 11 Master's theses, 14 Ph.D. theses, and 45 papers published in refereed scientific journals. All of these theses and papers (with bibliographic references) are listed below. All but one of the theses were used to fulfill the requirements for MIT degrees and are available from the MIT libraries. The one exception is F. Chen's Ph.D. thesis which was for a Harvard degree and is available from the Harvard libraries.

In addition to the work described in the citations listed below, the Grant has supported Research Assistant Amy Solomon during the past two years to carry out a study of how baroclinic adjustment is affected by vertical resolution, vertical temperature structure, and dissipation. Ms. Solomon plans to use this project for her Ph.D. thesis. Support for this project will continue under NASA Grant NAG 5-2490, "The Factors Controlling Poleward Heat Transport in Climate Models."

Master's Theses

- 1974, J.R. Kroll, On the Centrifugal Instability of Nonaxisymmetric Flows.
- 1977, J.C. Barnard, On the Sensitivity of an Atmosphere in Radiative-Convective Equilibrium to Soil Moisture.
- 1977, D.A. Stewart, A Numerical Investigation of Layer Cloud Instability.
- 1979, C.A. Cardelino, A study of the Vertical Propagation of the Planetary Waves and the Effects of the Upper Boundary Layer.
- 1979, J.S. Scire, A higher Order Closure Turbulence Model of the Planetary Boundary Layer.
- 1981, S.J. Ghan, Modelling the Synoptic Scale Relationship between Eddy Heat Flux and the Meridional Temperature Gradient.
- 1982, G. Salustri, Diagnostic Study on the Forcing of the Ferrel Cell.
- 1986, P. Hancock, An Observational Study of Blocking with Regard to the Theory of Coherent Structures in a Baroclinic Atmosphere.
- 1987, J.S. Risbey, An Analysis of Zonal Mean Atmospheric Angular Momentum and High Cloud Cover Periodicities, Time-Latitude Structure, and Cross Correlations.
- 1987, P. Sousounis, Investigation of a Two-Dimensional Theory to Predict Ascending Motion at the Top of the Planetary Boundary Layer in the Tropics.
- 1992, S. Park, Diurnal Cycle of Deep Tropical Convection.

Doctoral Theses

- 1973, F. Chen, Finite Amplitude Baroclinic Waves with Mean Horizontal Shear (Harvard Degree).
- 1974, A. Bass, Pseudospectral Numerical Study of Geostrophic Turbulence.
- 1974, A.D. Moura, The Eigensolutions of the Balance Equations over a Sphere.
- 1974, L.L. Schulman, A Theoretical Study of the Efficiency of the General Circulation.
- 1975, M.A. Cane, A Study of the Wind-Driven Ocean Circulation in an Equatorial Basin.
- 1979, C.A. Lin, Eddy Heat Fluxes and Stability of Planetary Waves.
- 1979, A.B. Mullan, A Mechanistic Model for Mid-Latitude Mean Temperature Structure.
- 1983, C. Nobre, Tropical Heat Sources and Their Associated Large-Scale Atmospheric Circulation.
- 1983, W.J. Gutowski, Vertical Eddy Heat Fluxes and the Temperature Structure of the Mid-Latitude Troposphere.

- 1984, T.G. Shepherd, Rossby Waves and Two-Dimensional Turbulence in the Presence of a Large-Scale Zonal Jet.
- 1984, S.E. Zebiak, Tropical Atmosphere-Ocean Interaction and the El Niño/Southern Oscillation Phenomenon.
- 1991, S. Zhou, The Role of Large-Scale Atmospheric Eddies in the Climate Equilibrium.
- 1992, N. Renno, Cumulus Convection Parameterization and Numerical Modelling of Moist Atmospheres.
- 1994, J. Risbey, On the Use of Climate Models to Assess the Impacts of Regional Climate Change on Water Resources.

Publications

- 1975, E. Rivas, Further Numerical Calculations of the Circulation of the Atmosphere of Venus, J. Atmos. Sci., 32, 1017-1024.
- 1975, P.H. Stone, S. Chow, W.J. Quirk, H.M. Helfand and R.J. Somerville, Seasonal Changes in the Atmospheric Heat Balance Simulated by the GISS General Circulation Model, Proc. WMO/IAMAP Symp. on Long-Term Climatic Fluctuations, WMO-No. 421 (World Meteorological Organization, Geneva), 383-389.
- 1975, J. Charney, P.H. Stone and W.J. Quirk, Drought in the Sahara: A Bio-Geophysical Feedback Mechanism, Science, 187, 435-436.
- 1976, J. Charney, P.H. Stone, and W.J. Quirk, Reply to "Drought in the Sahara: Insufficient Biogeophysical Feedback?", Science, 191, 100-102.
- 1976, A.D. Moura and P.H. Stone, The Effects of Spherical Geometry on Baroclinic Instability, J. Atmos. Sci., 33, 602-616.
- 1976, A.D. Moura, The Eigensolutions of the Linearized Balance Equations over a Sphere, J. Atmos. Sci., 33, 877-907.
- 1976, L. Merkin and E. Rivas, Rotating Stratified Flow over Finite Isolated Topography, J. Atmos. Sci., 33, 908-922.
- 1976, M. Cane and E.S. Sarachik, Forced Baroclinic Ocean Motions: I. The Linear Equatorial Unbounded Case, J. Mar. Res., 34, 629-665.
- 1977, E.K. Schneider and R.S. Lindzen, Axially Symmetric Steady State Models of the Basic State for Instability and Climate Studies. Part I. Linearized Calculations, J. Atmos. Sci., 34, 263-279.
- 1977, L.L. Schulman, A Theoretical Study of the Efficiency of the General Circulation, J. Atmos. Sci., 34, 559-580.
- 1977, M. Cane and E.S. Sarachik, Forced Baroclinic Ocean Motions: II. The Linear Equatorial Bounded Case, J. Mar. Res., 35, 395-432.

- 1977, E.Rivas, A Numerical Scheme to Solve Unstable Boundary Value Problems, Advances in Computer Methods for Partial Differential Equations, 2 (IMACS, Rutgers University).
- 1977, J. Charney, W.J. Quirk, S. Chow, and J. Kornfield, A Comparative Study of Albedo Change on Drought in Semi-Arid Regions, J. Atmos. Sci., 34, 1366-1385.
- 1977, J. Charney, "A Biogeophysical Feedback Mechanism in Arid Lands," Chapter 13, in Arid Zone Development, Ballinger Publishing Co., Cambridge, MA, 181-188.
- 1978, P.H. Stone, Baroclinic Adjustment, J. Atmos. Sci., 35, 561-571.
- 1979, P.H. Stone and J. H. Carlson, Atmospheric Lapse Rate Regimes and their Parameterization, J. Atmos. Sci., 36, 415-423.
- 1979, D. Randall, The Entraining Moist Boundary Layer, Fourth Symposium on Turbulence, Diffusion, and Air Pollution, Amer. Meteor. Soc., Boston, 467-470.
- 1980, D. Randall, Conditional Instability of the First Kind Upside Down, J. Atmos. Sci., 37, 125-130.
- 1980, J. Charney and D.M. Straus, Form-Drag Instability, Multiple Equilibria and Propagating Planetary Waves in Baroclinic, Orographically Forced, Planetary Wave Systems, J. Atmos. Sci., 37, 1157-1176.
- 1981, J.G. Charney, J. Shukla and K.C. Mo, Comparison of a Barotropic Blocking Theory with Observation, J. Atmos. Sci., 38, 762-779.
- 1981, J.G. Charney and J. Shukla, Predictability of Monsoons, in Monsoon Dynamics (Cambridge University Press, Sir James Lighthill and R.P. Pierce, eds.), pp. 99-109.
- 1981, M. Cane, V. Cardone, M. Halem, and I. Halberstam, A simulation Study of the Impact of SEASAT-A on Weather Prediction, J. Geophys. Res., 86, 8093-8106.
- 1981, M. Cane and E.S. Sarachik, The response of a Linear Baroclinic Equatorial Ocean to Periodic Forcing, J. Mar. Res., 39, 651-693.
- 1981, M. Cane and D.W. Moore, A Note on Low Frequency Equatorial Basin Modes, J. Phy. Oceanogr., 11, 1578-1584.
- 1981, M. Cane and V. Cardone, The Potential Impact of Scatterometry on Oceanography: A Wave Forecasting Case, Oceanography from Space, (J.F. Gower, ed., Plenum Press, New York), pp. 587-596.
- 1982, M. Cane, The variability of Equatorial Currents, Recent Progress in Equatorial Oceanography (S.P. McCreary, D.W. Moore, J. Witte, Eds., Nova/NYIT Press, Ft. Lauderdale, Florida), pp. 197-206.
- 1982, M. Cane and E.S. Sarachik, Linear Baroclinic Response of Equatorial Oceans to Periodic Forcing, Recent Progress in Equatorial Oceanography, (S.P. McCreary, D.W. Moore, J. Witte, Eds., Nova/NYIT Press, Ft. Lauderdale, Florida), pp. 365-372.
- 1982, P.H. Stone, S.J. Ghan, D. Spiegel and S. Rambaldi, Short-Term Fluctuations in the Eddy Heat Flux and Baroclinic Stability of the Atmosphere, J. Atmos. Sci., 39, 1734-1746.

- 1982, M. Cane and Y. du Penhoat, On the Effect of Islands on Low Frequency Equatorial Motions, J. Mar., Res., 40, 937-962.
- 1982, S.E. Zebiak, A Simple Atmospheric Model of Relevance to El Niño, J. Atmos. Sci., 39, 2017-2027.
- 1983, M. Cane and E.S. Sarachik, Equatorial Oceanography, Rev. Geophys. Sp. Phys., 21, 1137-1148.
- 1983, G. Salustri and P.H. Stone, A diagnostic Study of the Forcing of the Ferrel Cell by Eddies, with Latent Heat Effects Included, J. Atmos. Sci., 40, 1101-1109.
- 1984, S.J. Ghan, Empirical Models of the Eddy Heat Flux and Vertical Shear on Short Time Scales, J. Atmos. Sci., 41, 398-401.
- 1984, P.H. Stone and G. Salustri, Generalization of the Quasi-Geostrophic Eliassen-Palm Flux to Include Eddy Forcing of Condensation Heating, J. Atmos. Sci., 41, 3527-3536.
- 1985, W.J. Gutowski, A simple Model for the Interaction Between Vertical Eddy Heat Fluxes and Static Stability, J. Atmos. Sci., 42, 346-358.
- 1985, W.J. Gutowski, Baroclinic Adjustment and Mid-latitude Temperature Profiles, J. Atmos. Sci., 42, 1733-1745.
- 1986, R. Markson, Tropical Convection, Ionospheric Potentials, and Global Circuit Variation, Nature, 320, 588-594.
- 1987, P.M. Rizzoli and P.J. Hancock, Coherent Structures in a Baroclinic Atmosphere. Part IV: A Comparison between Theory and Data, J. Atmos. Sci., 44, 2506-2529.
- 1987, T.G. Shepherd, Rossby Waves and Two-Dimensional Turbulence in a Large-Scale Zonal Jet, J. Fluid Mech., 183, 467-509.
- 1987, T.G. Shepherd, A Spectral View of Nonlinear Fluxes and Stationary-Transient Interaction in the Atmosphere, J. Atmos. Sci., 44, 1166-1178.
- 1988, J.S. Risbey and P.H. Stone, Observations of the 30-60 Day Oscillation in Zonal Mean Atmospheric Angular Momentum and High Cloud Cover, J. Atmos. Sci., 45, 2026-2038.
- 1993, S. Zhou and P. H. Stone, The Role of Large-Scale Eddies in the Climate Equilibrium, Part I: Fixed Static Stability, J. Climate, 6, 985-1001.
- 1993, S. Zhou and P.H. Stone, The Role of Large-Scale Eddies in the Climate Equilibrium, Part II: Variable Static Stability. J. Climate, 6, 1871-1880.
- 1994, N.O. Renno, K.A. Emanuel, and P.H. Stone, A Radiative-Convective Model with an Explicit Hydrological Cycle, Part I: Formulation and Sensitivity to Model Parameters. J. Geophys. Res., in press.
- 1994, N.O. Renno, P.H. Stone, and K.A. Emanuel, A Radiative-Convective Model with an Explicit Hydrological Cycle, Part II: Sensitivity to Large Changes in Solar Forcing. J. Geophys. Res., in press.